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Afghanistan: Solar assets, electricity production, and rural energy factors

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ABSTRACT

Satellite-based solar insolation models and data collected in 2004–05 show large solar assets for the southern and western regions, dry and high reflective zones like deserts, plateaus and upland pasture hillocks. For Afghanistan, both lower latitude plus high-plateau terrain result in excellent solar assets. Afghanistan has landform class of high alpine close-spaced mountains and basin zones with extreme dryness and low rainfall, and high air turbidity. Elevations and air turbidity (evidenced by wind maps, not covered here) suggest high renewable resources. The infrastructure of present electric sector is based upon small hydro, diesel thermal, in place in pre-2001, but now 61% of electrical power is imported from northern neighbor countries. However, total electricity output, today, is about 2× that of 2006 due to success of this import strategy. Trends from 2006 onwards show increases of about 25% per annum. 78% of population is rural, use traditional fuels, and have a very low ownership of electricity appliances. Rural settlements lack all 3 components (generation/transmission/local grids). Finally, we note the country's serious water quality issues and report on small scale solar thermal using evacuated collectors and continuous flow principles in order to produce clean water by hygienics of pasteurization.

Contents

1. Solar assets

Since the Bonn Agreements of 2002, Afghanistan' passage has turned from 2 decades infrastructure-destruction to last 8 years of slow rebuilding. Our purpose is to report on solar assets and current electricity production. We shall also show some recent research on energy use of rural households [11]. In order to expand resources on Southeast Asia region solar assets, NREL has published extensive data and tools on solar assets of Afghanistan and Pakistan [12].[1] The study used Meteosat-5 platform with excellent geometry and 40 months (2002–05) of hourly data.[2] Researchers used 3 radiation-transfer-models and produced 2 levels of geo-grids (40 km × 40 km and 10 km × 10 km). To compare models, researchers used a test "border frontier" zone, characterized by highly variable weather conditions; this zone has strong monsoons regime and very distinct winter–summer trends. This test and model comparisons indicate high data quality. Researchers compared the NREL models with the SUNY model

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[1] USAID funds renewable energy work under SARI/e. National Renewable Energy Laboratory [NREL] provided authorship, publication, and contract management; SUNY, State University of New York (Albany) provided scientific support, calibration analyses, and SUNY model comparisons. http://www.nrel.gov/applying_technologies/afghanistan.html.

[2] Meteosat Visible and Infrared Imager (MVIRI) instrument for water vapor, visible and infrared; the space platform is a geostationary at 64° East (Indian Ocean).

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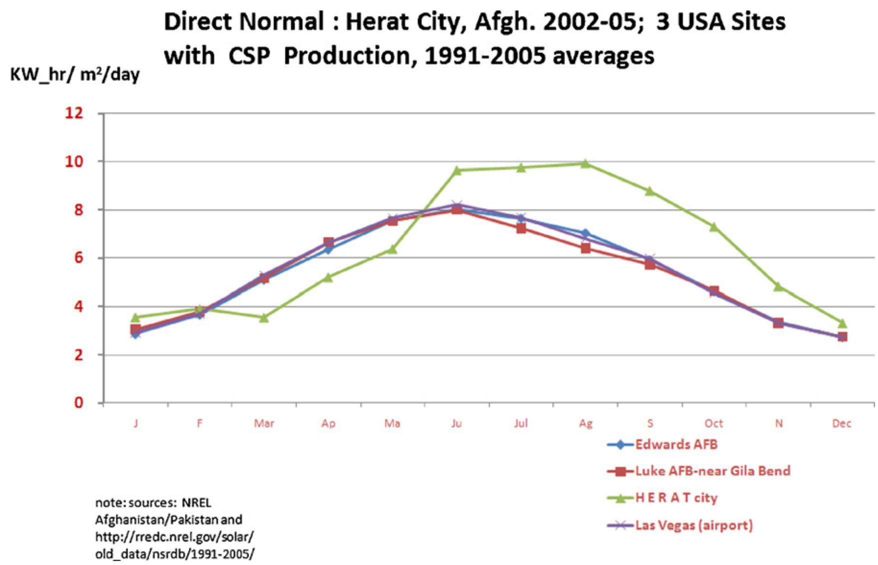

Chart 1.

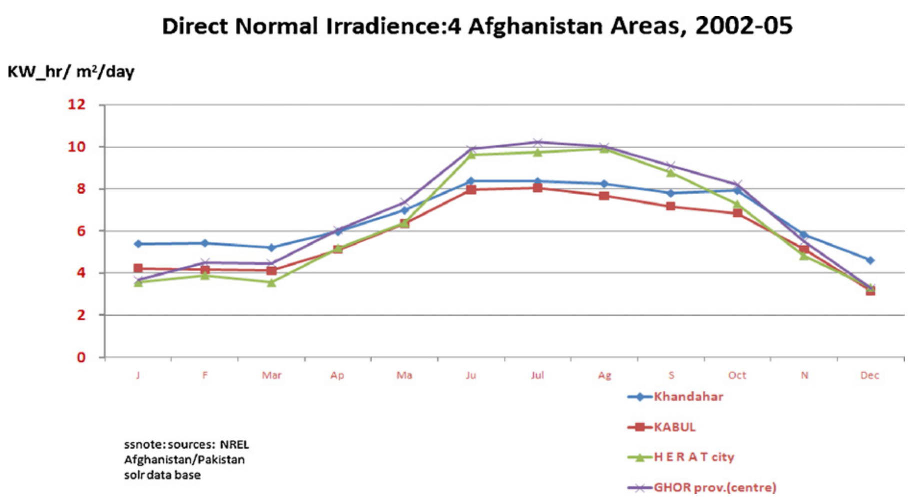

Chart 2.

and found SUNY results midway between the 2 others.[3] The SUNY model is "more ample" and includes metrics on water vapor in a condensate stage, stratospheric ozone, Atmosphere Optical Depth (AOD), daily snow cover, and vertical elevation.

Overall results show that Afghanistan is a "sunbelt" country as found in its latitude-equal parts of USA Southwest.[4] Taking into account land use, terrain, slope, and weather factors, Menos and Perez estimate that 5 southwestern states have about 6.88 million MW capacities available for solar-CSP. They used a filter to exclude land with (a) high terrain slopes, (b) less than 6.75 kW/m^2/day, and (c) land adverse to industrialization such as national parks, urban areas, and wildlife zones. For Afghanistan, such details do not yet exist, but the NREL data do suggest that the country regions (South, West) where imports today do not serve, have equal or greater assets for Concentrated solar technology.

Afghanistan shows very high values of solar assets eastwards from Iranian frontier and centered on Ghor province with summer monthlies that peak to 9.0 kW h/m^2/summer day. Such "high solar" zones are close the populated Harirud river valley, Herat city. The NREL maps also show high solar areas in southern half of country, including the Kandahar metro region and Helmand Valley.

Chart 1 compares Ghor province with regions of major CSP plants in USA Southwest to Ghor Province, a very high solar region. The USA sites are SEGS at Kramer Junction, Nevada One, and the 280 MW (planned) plant at Gila Bend, Arizona. Chart 2 compares 3 of Afghanistan's largest cities with Ghor.

2. Electricity production

Due to the civil war and changes in government, our research is uncertain on Afghanistan's power industry prior to 2002. Daniel Balland, with W. Floor and B. Hourcade, an Afghanistan scholar, gives the following for early years[5]:

[3] Perez et al. [12] discuss comparisons, using 3 models (SUNY, NREL-CSR, NREL-SSE). On the method of creation of a global gridded data set on the AOD (aerial optical depth) data, the global program is discussed by Gueyard and George [6]. For Afghanistan, single-number monthly averages for AOD were used, suggesting a caution to users of Afghan solar data;NREL personnel, such as R. George and D. Renne have helped author on understanding this caution.

[4] Menos and Perez did a layman's report on the great potential of solar in 5 southwestern states [10].

[5] Balland D, Floor W, Hourcade B. "BARQ (2)" in <http://www.iranica.com/>; search on 14.09.2009.

Table 1
Da Moesa Breshna (electric company) annual electricity generation outputs.

	MW h	% Share		
		Hydro	Diesel-thermal	Imports
2006	1,289,477	49.9%	16.5%	35.5%
2007	1,574,790	48.0%	13.4%	38.6%
2008	1,566,533	39.4%	12.6%	48.0%
2009	2,082,571	40.1%	4.5%	55.5%
2010	2,583,780	35.2%	3.9%	60.9%

Source: http://www.afghnaneic.org/; site is Afghan Energy Information Center (AEIC), supported by USAID; accessed and updated as of 05 Feb., 2011.

Of a total generating capacity of 419 mw divided among 40 plants, hydroelectricity accounts for 70 percent (294 mw), steam power for 23 percent (97 mw), and diesel power for 7 percent (28 mw). The development of this distribution ratio over the last fifteen years has been marked by a diminution in the relative importance of hydroelectricity, which reached an effective maximum of 95 percent of generating capacity around 1970.

2.1. Da Moesha Breshna, Afghan electric monopoly

The government-owned Da Moessa Breshna has been the provider of transmission, generation, distribution. A USAID project on energy statistics reports total national MW h produced, and plant-by-plant outputs. National trends show a decrease in share from hydro, sharp reductions for the older, polluting plants with diesel-thermal, and dominant share by imports to current 61% of output (Table 1). Imports are from: Tajikistan, Uzbekistan, Turkmenistan, Iran.

By end of 2010, recent investments in hydro show payoffs in following plants (latest year MW h in parentheses): Naghlu (321,873 MW h), Kabul Sarobi (185,011 MW h), Mahipar (117,084 MW h) in East; in South, Kajaki (One and Three) produced 175,218 MW h; Kajaki Three came on-stream in Oct., 2009 and with Kajaki One accounts for about 2/3 of all power of Afghanistan-South. In short, volume from Hydro has increased by 4× since Balland's account of the 1970 period.[6]

In summary, production from electricity monopoly, Da Moessa Breshna, production (a) has doubled (increased, about 25% per annum) since 2006, (b) shows slight decreases in the hydro share, (c) increased imports so that these are such increases so that imports are now dominant at about 61% of national total. Observers report that private production, or self-generation, is common, especially in Kabul. A 2005 study by Hill International, based upon door-to-door surveys, estimates that (a) only 2/5ths of Kabul households are "in grid connected geography" and (b) self-generation, by petrol and diesel, exceeds the grid-supplied power on the total supply of 550 MW h annually for Kabul metro.[7] A solar retail market has started. A major global manufacturer, active for over 4 years in all provinces, reports a rising trend of solar PV sales.[8]

In the past year, Da Moessa Breshna has undergone corporatization and management change. For this writing, no current financial benchmarks were available. But, ADB's study of 2005 operations shows signs of financial struggle; we have re-analysed the ADB numbers to show (a) on a basis of "billed" hours only, there is

[6] For output by plant and region www.afghaneic.org; accessed on 04 Feb, 2011.

[7] Hill International [7], Table 5-R; Tables 5-P thru W show self-generation vs. grid connected for 4 sectors (government, commercial, large industrial, residential). The Hill Int'l results are old; data from AEIC shows about 251,000 residential customers in Kabul-which may be between 35% and 65 % of Kabul households.

[8] Bill Rever, British Petroleum-Solar, Afghan American Chamber of Commerce Annual meetings, October, 2007, Washington, DC. BP-Solar, by partnership with BP-TATA -Afghanistan has market presence in all provinces and reports "several hundred thousand watts per year in sales."

Table 2
Annual expenses per kW-H "Billed".

	National	Kabul department
Fuel + materials	$0.024	$0.024
Rents (including imports)	$0.012	$0.024
Salaries	$0.010	$0.024
Misc	$0.007	$0.024
Total exp	$0.052	$0.056
Net income	$0.007	$0.015

Source: As in footnote 6.
Note 1: 533 GW hours is "billed" total; imports + production = 856.66 GW h.
Note 2: Data are for year 2004 only; costs exclude any subsidy for purchase of diesel fuel.
Note 3: Net income is simply: Total Revenue (less) Expenses.

some average per unit net income, (b) when financials are recast (not shown here), due to 38% of "non-billed" production, DABM is a loss-making firm (Table 2). The Kabul department has a share of about 49% of national total output. Table 2 strongly suggests that the monopoly operates at average costs significantly below average revenue, due to the low collections, technical losses, and likely failures in billing/meter-reading controls.[9] Poor economics and poorer service quality, at least in 2004, are shown in the evidence that about 38 MW h, or 2/3 of government-NGO sector power needs were, 6 years ago, met by self-generation. A 2005 World Bank survey shows that many firms assert they cannot get grid connection and self-generation propels upwards high costs of manufacture;thus, since may Afghan firms are start-ups or small-scale, tghe lack of grid power pushed firms to expensive self-generation [16].

3. Rural demography

In a compact phrase, Afghanistan demography is "dominantly settlements, small and remote, and marked by pre-modern means of transport, energy use, and non-technological agriculture." Rural is 78% of total population, a settlement pattern that roughly resembles the USA in its pre-urban explosive growth of 1880s. On urban population, Afghanistan differs extremely from USA of 19th century which lacked a "primate city". Kabul is a true and singular "primate city" with 13% of total and 6 cities with another 9%. Provinces are (with % urban shown): Kandahar (35.7%.) Balkh (24.5%) Herat (24.1%), Condos (21.0%), Baghman (15.3%). World Bank estimate growth rate of Kabul metro at 15% per year and a substantial growth of "informal" (that is "illegal") building without sewerage and electricity on non-used urban land.[10]

A summary of the demography is: national population is reckoned at 29.2 million persons, [11] with infant (0–1) mortality at 152 per 1000 births and Under 5 mortality at 225 per 1000 born. The preceeding are national estimates; recent evidence points tp higher child mortality in rural; the 2005 AHS [11] used a disciplined methodology and reached about 3/4% of rural sample clusters, in spite of wartime conditions; The AHS has excellent summary on metrics-issues with the Brass household questions.[12] Rural child

[9] For Table 2 costs are in ADB [2]; ratios were calculated by the author.

[10] World Bank, SASEI Report [17].

[11] We follow USA Bureau of Census http://www.census.gov/compendia/statab/2010/cats/international_statistics.html.

[12] Our conclusions, namely, that rural child mortality levels have much statistical uncertainty are based upon the AHS and elephone contact with Prof G. Becker [11]. However, child mortality seems on a downward trend, is one uses the 1974 survey as "baseline" and analyzed in a 1979 peer-review journal, which relied upon the "initial model" of William Brass technique. based upon the technical analysis of questions are asked on children "ever born/still living." These are Brass questions (named for the British demographer, William Brass). Data analysis very strongly suggests that both births and deaths of young girls are much under-reported and

Table 3
Rural households: reported ownership of goods.

	% Hhds owning
Sewing machine	52.2%
Clock	79.3%
Kero lamp	94.7%
Pressure cooker	56.9%
Radio	48.4%
TV	19.8%
Bike	21.2%
Motorbike	8.6%
Electricity generator	6.4%
Car	3.6%
Trac:cr	1.4%
Refrigerator	1.4%

Source: AHS [11], Table 3.4.
Note 1: base = 8240 reporting households.

mortality is likely worse than national, perhaps by a factor of 1.25 to 1.5.

The AHS reports a household size of 6.9 persons, but the prior research strongly says that "permanent" size is larger, due to indicators in the survey responses (such as absences of young men). But the rural population is also very child intensive: 23% are girls and 24.6% of men are boys (both genders under age 15).

In rural, among the segments under age 19 and school-age, less than 1/2 are enrolled in school. However, the AHS shows a favorable rise in school-attendance rates among young non-married, rural women. In rural, young women, although showing current school rates lower than among young rural men, have attendance rising from pre-2001 levels; however, for rural women, marriage seems to be a critical factor in leaving school, so that over 94% of ever-married women have no schooling at all [11].

4. Rural household electric use

The AHS reports use of energy appliances (Table 3). The survey data underscore how rural villagers cope with the "gap" between household tasks and energy needs. Table 3 shows that only 54% of households report a pressure cooker-only 1.4% report a refrigerator. Based upon the ownership of "durables" and Principal Components Analysis (PCA), this means that only the wealthiest households can purchase such "appliances." For this and other reasons, the USA government has funded a 3-year project to install low-voltage solar photovoltaic systems in some rural vllages under ACEP (Afghan Clean Energy Program). The AHS has an excellent battery of water use/water source questions.[13] The survey includes items on solar purification but, to today, the "drinking water" behaviors have not been published. The AHS analyzes how "wealth" is related to schooling and media usage. The wealth index is based on a principal components analysis of quintiles. Households with more possessions (and electrical appliances) or are "wealthy" are more likely to use mass media, have higher current and lifetime school attendance, higher media usage (listening/watching) TV and radio.

A good picture on rural "remoteness" comes time-and-distance-to-travel to clinics: about 75% of women go to clinic by foot, in which about 60% need 2 or more hours of travel time; this is one-way transit. Only 24% of trips have motor-vehicle/donkey/bicycle for the travel. Only about 10% of households own such mechanics. About 20.3% of women report 3 or more hours of travel; when independently verified by a use of geographic metrics, this rises to 27.2% of mothers who take 3+ hours of travel for a single one-way trip. To planner-engineers rural Afghanistan is a challenge; a first start is provision of roads, but, for households, the chief water providers, namely women, lack transport; the AHS has crude indications that the households spend much labour hours for water collection for basic needs: drinking, bathing, cooking, clothing.

that child mortality, ages 0–5, is among highest in world; the Brass method provides a "backward-looking" view of mortality and the researchers note well the large improvements in coverage of child vaccinations for Afghanistan rural; see MOPH-JHU/IIHMR, pp. 30–40.

[13] The AHS includes about 9 questions on water use (including chlorine, solar purification) the question on "use of toilets/latrines is reported but has a large amount of "missingness"-indicating a methods/wording/understanding issue.

5. Some recent solar engineering approaches on small scale solar-thermal

5.1. Water quality issues

UNICEF has used multi-purpose household surveys to find out about "sources" (such as dug wells, surface flows) to report on "safe and non-safe water sources"; such indicators are so broad that they give no guidance to project design nor selection of technology.[14] The start of scientific hydrologic and water testing regimes has begun with team efforts of USGS and Afghan engineers. 2004 research shows potent problems in Kabul city which depends upon neighborhood-managed tube and pit wells. A combined Afghan-USGS team tested 108 wells and indicated several chemical and water solid levels which exceed safety standards for drinking water.[15]

On use of its ample solar to purify water, there are "how to" manuals, but not an abundance of "ready to use" devices that can help Afghanistan.[16]

The Ministry of Rural and Rehabilitation Development has funded very small-scale energy programs with renewables under its National Solidarity Program. To date, we know of some issues in the evaluation results of 185 rural projects, small in scope (under $1000 USD grants).[17]

5.2. Small scale solar treatments by pasteurization

New, recent approaches to small-scale solar have promise for Afghanistan:

- W. Duff and D. Hodgson report on a density-driven continuous flow system, where the energy source are solar collectors, flat-panel, with evacuated (glass insulation) tubes; Materials are copper, glass, PVC and low-cost framing (such as wood). The Duff–Hodgson approach relies upon the hygienics of pasteurization.[18] The test system has a tube and shell heat exchanger but needs no electric pumps. The system avoids all wasteful boiling and insures that the final product is completely treated in pasteurization process. Authors show (a) high daily production from 82 to 226 kg/day under moderate sun (test days, October/September). The researchers' more recent report says that production was over 150 liters of purified water per day and that "holding times", proper to pasteurization hygienics, of 1 min or more are possible.[19] Currently, W. Duff is refining the test system with a very superior heat exchanger; the engineering team, Colorado State University, has conducted drills on "assembly and installation" with high school students to reduce to 1–2 hours training needed by village users.[20]

[14] UNICEF [14].
[15] Broshears et al. [3]. USGS project site [15] has pointers to (a) the follow-up recharge study of some Kabul wells, (b) remote sensing maps which show sample points, topological contours, and surface-water-streambed features.
[16] Argaw [1].
[17] Selvarajan [13].
[18] Duff and Hodgson [4].
[19] Most recent update in Duff [5].
[20] Discussions are started with manufacturer, Solar Panels Plus as potential OEM for small scale systems; see www.solarpanelsplus.com.

5.3. Conclusion

Afghanistan's formal energy sector (the government-owned providers of natural gas and electricity) face pressures of urban population growth, rural poverty, and rising demand shown by the surge in self-generating electric users and high levels of usage of traditional fuels (firewood, charcoal, etc.) for household space heating/food preparation other non-power energy consumption. Presently, the power industry does not use solar, but at household level, a retail market has begun. Presently, many barriers exist, such as the lack of a private capitalized electricity sector and deterrents to private investment in large scale solar. Hopefully, donor groups and domestic policymakers will look at the country's very large solar downflux as a dominant energy source for next decade.

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